PB87-208351

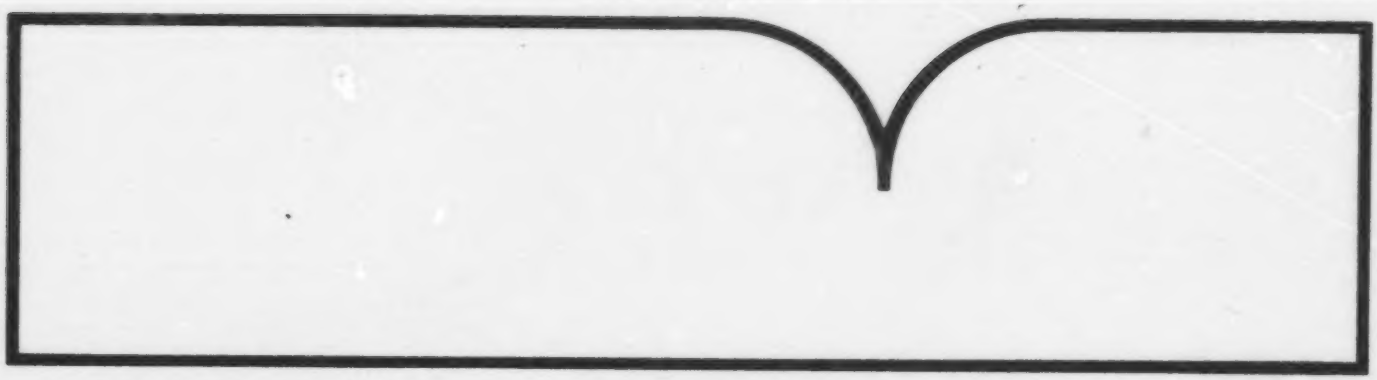
# Development of a Sampling System for Surface Dust-Borne Contaminants

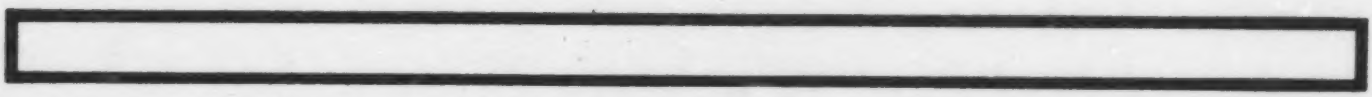
Environmetrics, Seattle, WA

Prepared for

Environmental Monitoring Systems Lab.
Research Triangle Park, NC

Jul 87





U.S. Department of Commerce
National Technical Information Service
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EPA/600/D-87/220
July 1987

PB87-208351

# DEVELOPMENT OF A SAMPLING SYSTEM FOR SURFACE DUST-BORNE CONTAMINANTS

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ENVIRONMENTAL MONITORING SYSTEMS LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

**TECHNICAL REPORT DATA**
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| 1. REPORT NO. | 2. | 3. RECIPIENT'S ACCESSION NO. |
|---|---|---|
| EPA/600/D-87/220 | | |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| DEVELOPMENT OF A SAMPLING SYSTEM FOR SURFACE DUST-BORNE CONTAMINANTS | July 1987 |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) M. G. Ruby, John W. Roberts, Richard W. Boubel and Robert G. Lewis | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Envirometrics Seattle, WA | 10. PROGRAM ELEMENT NO. |
| | 11. CONTRACT/GRANT NO. 68-02-4406 |
| 12. SPONSORING AGENCY NAME AND ADDRESS U. S. Environmental Protection Agency Environmental Monitoring Systems Laboratory/RTP Methods Development & Analysis Division/MDB Research Triangle Park, NC 27711 | 13. TYPE OF REPORT AND PERIOD COVERED |
| | 14. SPONSORING AGENCY CODE EPA/600/09 |

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A prototype surface sampler has been manufactured by Cascade Stack Sampling Systems, Inc. (CS3) with the design objectives of collecting a known and reproducible portion of the surface dust on a variety of surfaces and the low and medium volatility organics found on the dust. An additional design objective is to be capable of collecting more than 2 grams of floor dust in an average house in two to three minutes of sampling. The design is based on a marriage of the proven high volume stack sampler (Boubel, 1971 and ASTM, 1987) and pesticide sampler (U.S. EPA, 1977).

The high volume surface sampler (HVS2) is constructed of stainless steel and aluminum and weighs approximately 50 pounds. A two speed, one horsepower blower is remotely mounted and adds about 8 more pounds to the system weight. The entire sampling system is designed with quick removal clamps and gas tight joints to permit easy sample recovery and cleanup.

The sampler has a nominal flow rate of 30 cfm at standard temperature and pressure although the flow can be reduced to 4 cfm if desirable. The flow is measured by a calibrated (NBS traceable) laminar flow element (LFE).

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| | | |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
|---|---|---|
| RELEASE TO PUBLIC | UNCLASSIFIED | 16 |
| | 20. SECURITY CLASS *(This page)* UNCLASSIFIED | 22. PRICE |

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

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# DEVELOPMENT OF A SAMPLING SYSTEM FOR SURFACE DUST-BORNE CONTAMINANTS

## Introduction

Recent studies of human exposure to air pollutants have increasingly recognized the importance of pathways other than inhalation (Ott et al., 1986). Ingestion of air pollutants deposited in water or soil is potentially the source of a significant portion of an individual's total pollutant burden, especially for very young children, with their lower body weight and frequent hand-to-mouth activity

Dust can be both a medium for the transfer of pollutants from sources to people and a medium for the accumulation of pollutants. At present there is no validated method for sampling the dust present on surfaces, although a wide variety of techniques have been used by various researchers. Unfortunately the methods used permit little comparison between one study and another.

A useful sampling technique should have a known and reproducible removal rate of dust on various surfaces and be able to achieve a relatively constant efficiency at different loadings of surface dust accumulation. In addition, the procedure should be able to collect and measure the low and medium volatility organics which are expected to be found on dust particles. Finally, the data collected should be capable of being compared to the actual dust uptake by a test subject. This paper reports on the development of a sampler designed to meet these objectives.

## Public Health Implications of Surface Dust

Particulate matter, especially fine, carbonaceous particulate matter, has been shown to be an efficient scavenger, by adsorption, of semi-volatile materials and other particles (Natusch and Wallace, 1974). House dust, in particular, has been found to be coated with a wide variety of other, smaller particles and droplets of organic materials (Haeske et al., 1957).

The metals in house dusts, particularly lead and cadmium, have been extensively studied (e.g., Vostal et al., 1974; Solomon and Hartford, 1976; Harrison, 1979; Diemel et al., 1981; Seifert et al., 1984; Rabinowitz et al., 1985). Organic materials in house dusts have also been analyzed (e.g., Haeske et al., 1957; Yocom et al., 1971; Starr et al., 1974; Davies et al., 1975; Imhoff et al., 1982; Lioy et al., 1985).

Most children go through a phase of putting things in

their mouths. For children in the crawling stage, this means putting fingers into their mouths that have been in contact with the floor or ground. Various studies have estimated that between 10 and 32 percent of small children also compulsively eat non-food material, such as dirt, soap, paper, or paint chips, a practice termed pica (Lin-fu, 1973). The toddler has only about one-fifth the body weight of an adult and ingests an estimated 2.5 times, or more, as much dust, which increases the potential health risk to the child of contaminants in the floor dust at least 12 times (Hawley, 1985).

An estimate of average daily soil dust ingestion by small children ranges from 0.12 to 1.8 grams, depending on which element is used as the tracer (Binder, et al., 1986). Although the longer residence times of inhaled dust in the lung may mean that a greater percentage of inhaled toxic materials enter the blood stream, studies of children in areas of heavy contamination have found a better correlation between the body burden of pollutants and the amount of the pollutant on their hands than with the concentrations in the air (Roels et al., 1980). Davidson and Elias (1986) estimate that a two year old child could take in forty times as much lead from ingesting dust contaminated by air pollution as from directly inhaling lead particulate matter. Murphy and Yocom (1986) provide a worst case estimate of almost 1000 times as much long-lived soil toxics taken in by dust ingestion as by inhalation for a young child (2.5 years).

Childhood intake may represent a major source of the total adult body burden of some pollutants. Data developed by Henke et al. (cited by Fox, 1979) suggests that up to one-third of the adult body burden of cadmium may be accumulated by age three. Pinkerton (1973) reports that one-half of the adult cadmium and lead body burdens accumulate by late adolescence.

The integrated mutagenic activity of house dust has been found by several research teams to be significant, although the implications of the measurements are not clear (e.g., van Houdt and Boleij, 1984; Lioy et al., 1985; Roberts et al., 1987). The measurements of floor dust mutagenic activity by Roberts et al. (1987) are higher but comparable to the results from selected soils by Brown et al. (1985).

## Characteristics of House Dust

The sources of house dust are highly variable and studies have not provided any detailed generalization of its composition. Residues from food and food preparation, skin scales and other organic residue from the human and animal occupants of the house, fibers from clothing and household furnishings, fibers and minerals from building materials, organic matter from cleaning compounds, waxes, and other consumer products, fragments of vegetation and humus, and mineral particles, such

as clay and sand, have all been identified in house dust.

A study in six U.S. cities found between 37 and 86 percent of house dust was inorganic (of which about two-thirds was silica and clay), less than 1 percent to 5 percent was grease, and the remainder other organics (Balough, 1986). A German study (Haeske et al., 1957) found significant differences in the composition of air-borne dust, dust recovered from a horizontal shelf, and carpet dust. More dry organic matter was present in the air-borne and horizontal-shelf dust than the carpet dust, which had more silicaceous material. A greater percentage of the air-borne dust was soot and other small particles.

A limited survey of homes in two areas in Seattle, WA (Roberts et al., 1987) found an average accumulation of floor dust of 19 $g/m^2$ and an accumulation rate of 1.6 $g/m^2$/day. In three homes the ratio between the dust recovered from bare floors and from rugs was compared, and found to be much greater (ratios of 15 to 140 times) for rugs.

Schaefer et al. (1972) found a mean indoor dustfall rate of 0.02 $g/m^2$/day in 100 homes in five cities. The amount of accumulated dust on floors was measured by Solomon and Hartford (1976) in 12 residences to be approximately 1.2 $g/m^2$. The striking difference between the amount of dust observed depositing from the air to the floor and the amount of dust that accumulates on the floor suggests track-in as a major source. One study of lead in house dust which carefully compared the deposited (9.3 µg $Pb/m^2$-day) and accumulated (166 µg $Pb/m^2$-day) dust levels concluded that most of the lead is carried into the house with "dust particles, adhering to shoes, etc." (Diemel et al., 1981).

The accumulation of dust in rugs can be expected to vary with the type of carpet, the frequency and manner of cleaning, the sources of dust inside and outside the home, and the behavior of the occupants. Studies of vacuum cleaner efficiency have found the addition of a power-driven agitator increases the amount of dust and rug fiber pickup by a factor of 2 to 6. Removal efficiency from a flat (e.g., Persian) rug will be from 5 to 10 times that from a shag rug, and the removal efficiency from a plush rug will be approximately 3 times that from a shag rug (Balough, 1986).

The size distribution of dust removed from carpets in three studies in 1928, 1961, and 1975 varied little with time. Between 14 and 20 percent were retained on a 50 mesh screen and between 51 and 54 percent passed a 200 mesh screen (Balough, 1986 and Barager, 1961).

Pesticides and other organics with lower vapor pressure or higher polarity are expected to partition more to dust than to air, making house dust a potential major reservoir of persis-

tent pesticides, such as chlordane, and PAH compounds, such as benzo-a-pyrene (BaP). However, the proportion of semi-volatile organic compounds partitioned to the dust is not clear. Measurements by Bamesberger and Adams (1966) found between 16 and 98 percent of the 2,4-D herbicide esters in the particulate phase. Studies of house dust (Davies et al., 1975; Klemmer et al., 1975; Starr et al., 1974) have found significant levels of pesticides. Both BaP and pesticides have been measured at greater concentrations in house dust than in the soil near the houses (Davies et al., 1975 and Bailey, 1981).

## Sampling Techniques

A wide variety of techniques have been used for collecting dust. Moistened glass fiber filters wiped across surfaces that may collect dust are a standard technique in industrial hygiene (OSHA, 1977). Moistened towels have been used in a similar manner (Vostal et al., 1974). This procedure has also been used for collecting water-soluble ions from surfaces (Sinclair, 1982). Adhesive tape (Royster and Fish, 1965) has been used to lift dust from surfaces for visual examination. Dust fall jars (Seifert et al., 1982) and other test surfaces (Schaefer et al., 1972 and Anzai and Kikuchi, 1978) have been deployed to collect dust. Accumulated dust has been collected by brushing from seldom-cleaned surfaces (Weschler, 1978). Small test areas have been hand vacuumed using a cut section of tubing as a nozzle and collected on a small, high-efficiency filter (Solomon and Hartford, 1976 and Que-Hee et al., 1985). Dust samples have been collected from family-used vacuum cleaner bags (Angle and McIntire, 1979). Specially adapted (Diemel et al., 1981 and Milar and Mushak, 1982 ) and standard vacuum cleaners have also been used to collect samples directly, with some analysts sieving the collected dust to remove larger material (Harrison, 1979). With the exception of the work by Que-Hee et al. (1985), there has been very little effort made to validate the collection techniques used.

Ambient sampling for semi-volatile organic compounds, in contrast, has evolved to a proven sampling train (Lewis et al., 1977; Lewis and Jackson, 1982). Early measurements of ambient pesticides often utilized samplers similar to the high volume sampling system for ambient total suspended particulate (TSP). Study of these samplers led to the conclusion that substantial portions of the organic compounds were being volatilized and blown off the filter over the 24-hour sampling period (Lewis, 1976). In the current design, the particulate filter is backed up by a trap specific for capture of the semi-volatile organics. Open-cell polyurethane foam (PUF) has been found to be an effective collector for these compounds, with an overall recovery of 70 to 100 percent for many pesticides. Soxhlet extraction of the filter and the 3 inch long PUF plug permit analysis by gas chromatography.

## High Volume Surface Sampler

A prototype surface sampler has been manufactured by Cascade Stack Sampling Systems, Inc. (CS3) with the design objectives of collecting a known and reproducible portion of the surface dust on a variety of surfaces and the low and medium volatility organics found on the dust. An additional design objective is to be capable of collecting more than 2 grams of floor dust in an average house in two to three minutes of sampling. The design is based on a marriage of the proven high volume stack sampler (Boubel, 1971 and ASTM, 1987) and pesticide sampler (U.S. EPA, 1977). A photograph of the prototype unit is shown in Figure 1.

The high volume surface sampler (HVS2) is constructed of stainless steel and aluminum and weighs approximately 50 pounds. A two speed, one horsepower blower is remotely mounted and adds about 8 more pounds to the system weight. The entire sampling system is designed with quick removal clamps and gas tight joints to permit easy sample recovery and cleanup.

The sampler has a nominal flow rate of 30 cfm at standard temperature and pressure although the flow can be reduced to 4 cfm if desirable. The flow is measured by a calibrated (NBS traceable) laminar flow element (LFE).

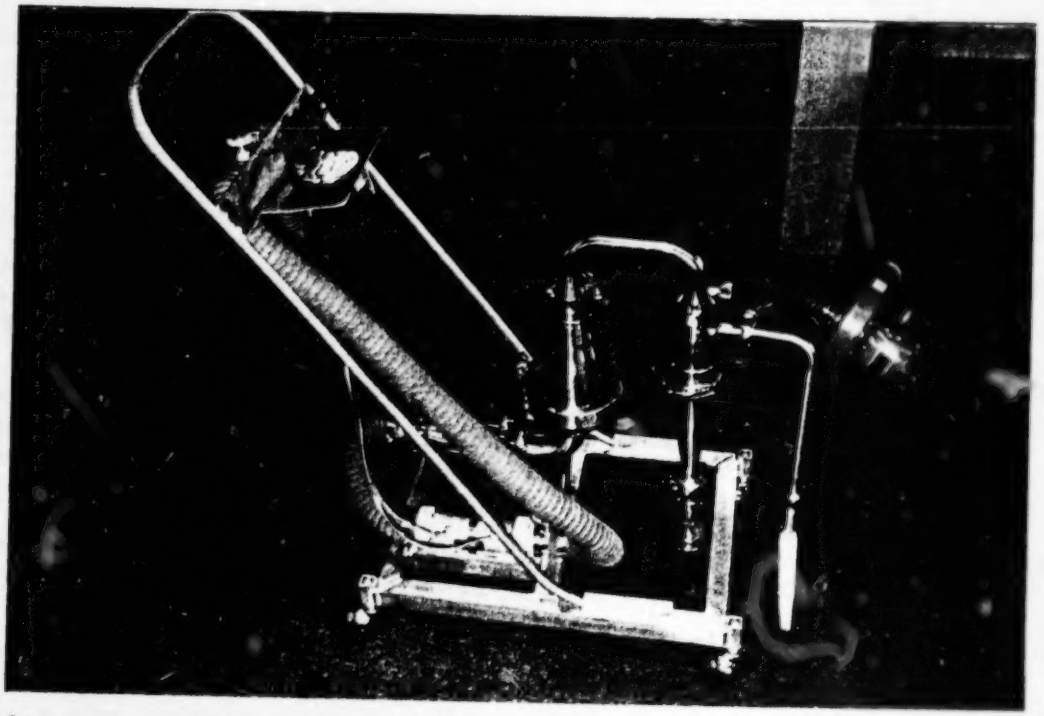

Figure 1. The prototype high volume surface sampler (HVS2).

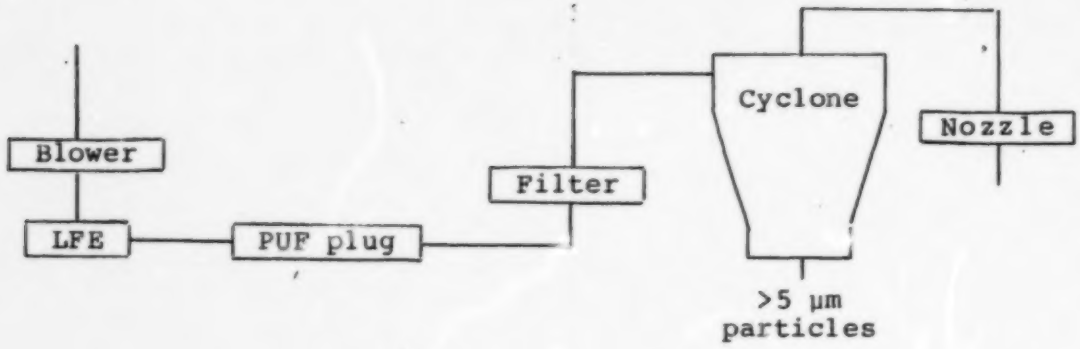


Figure 2. Air flow schematic of the high volume surface sampler.

As shown in the schematic in Figure 2, the dust is entrained in the air flow to a 0.375 inch by 10 inch slot nozzle which can be positioned at the desired distance above the surface. At the nominal flow rate of 30 cfm, the horizontal velocity across the surface is approximately 400 feet per minute when the nozzle is 0.5 inches above the surface. Previous studies of the threshold velocities for aeolian erosion of soil surfaces suggests that this is more than enough velocity to mobilize the surface dust (Gillette et al., 1980).

The sample passes from the nozzle to a 3 inch body diameter cyclone which has a calculated particulate cut diameter of 5 micrometers at the nominal flow rate. The actual cut size will, of course, vary with the flow rate and particle characteristics. The larger particles are removed by the cyclone and collected in the jar at its base.

From the cyclone, the sample passes into the filter section, which contains a 142 mm quartz fiber filter. Behind the filter is a canister containing the PUF plug where the semi-volatile organics are collected. The PUF is a 2 inch diameter plug, 3 inches long.

The blower is connected to the sampler by a flexible hose which allows the blower to be located out of the room being sampled. This prevents disturbance of the air in the area being sampled and also reduces the blower noise.

The sampler is mounted on an aluminum base frame with oversize casters at each corner. An alternative is to operate the sampler with a track-mounting if the surface is irregular.

Sampler testing

The testing procedures to establish the sampling characteristics and reproducibility of the HVS2 will rely heavily on

the established procedures for testing household vacuum cleaners (ASTM, 1979). This method measures the relative efficiency of vacuum cleaners on a standard carpet. In the testing of the sampler, two of the standard carpets, a plush and a level loop will be used. In addition, tests will be made on a smooth, painted surface.

The ASTM testing method defines a test dust which is 90 percent sand and 10 percent talc (both with specific size characteristics). The testing of the sampler will use two modifications of the test dust. In one, about 1 percent soot, from a mix of sources, will be added. In the other, the pesticides Dieldrin, Diazinon, and Chlorpyrifos will be mixed with the test dust. The collected dusts will be compared to the distributed dusts to determine the representativeness of the sample.

The standard testing method provides for only one level of dust accumulation, approximately 160 $g/m^2$. Because the tests of the sampler will require measurements at several levels above and below this, it will be necessary to establish that the dust distribution method is producing a relatively uniform spatial distribution of the dust so the level of accumulation under test is the actual value throughout the test. Similarly, the uniformity of the mix of soot and pesticide must be established.

Configuration testing of the sampler will include evaluation of the necessity of having the cyclone and the PUF filter. Optimal head heights for the three surfaces will be established for different dust loadings, with the objective of finding a single optimal head height or a single optimal head height for a given surface. The necessity of brushing a carpeted surface to obtain a reproducible and representative sample will also be tested.

The possibility that the PUF plug can be eliminated or replaced with a much shorter plug will be explored. Previous testing of the PUF plug was for a much longer time period and at a lower flow rate.

Data quality control will include test and lab blank samples and replicates of most test conditions. The pesticide analysis sensitivity and data quality objectives will be used to guide the formulation of the pesticide-bearing test dust. Analytical practices intended to lower the background during the pesticide measurements will be followed (Sherma, 1981).

## Applications

The HVS2 can be used to measure complex mixtures of metals, solids, and organics on many surfaces. Perhaps one of the most obvious uses is in support of studies of the health effects of

indoor air pollutants and studies of the relative importance of pollutant pathways. Outdoors, the sampler could be used to measure pollutant accumulations in air-mobilized soil surfaces. This might be useful in investigations of the potential risks associated with fugitive dust from hazardous waste land disposal sites, for example.

Acknowledgements

The authors are grateful to Jack Hirsch of CS3 for his work in the design and construction of the HVS2 and to the Hoover Company for their continuing assistance to this project. Although the research reported in this paper was funded wholly or in part by the U.S. Environmental Protection Agency through contract 68-02-4406, this paper has not been subjected to Agency review. Therefore, it does not necessarily reflect the views of the Agency, and no official endorsement should be inferred. Any mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

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